

PATENT COOPERATION TREATY

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

United States Patent and Trademark
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Crystal Plaza 2
Washington, DC 20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year)
02 June 1999 (02.06.99)

International application No.
PCT/FI98/00705

Applicant's or agent's file reference
2971070PC/TA

International filing date (day/month/year)
09 September 1998 (09.09.98)

Priority date (day/month/year)
12 September 1997 (12.09.97)

Applicant

UOSUKAINEN, Seppo et al

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
12 April 1999 (12.04.99)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Jean-Marie McAdams

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

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NOTICE INFORMING THE APPLICANT OF THE
COMMUNICATION OF THE INTERNATIONAL
APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

From the INTERNATIONAL BUREAU

To:

KOLSTER OY AB
Iso Roobertinkatu 23
P.O. Box 148
FIN-00121 Helsinki
FINLANDE

- 6 - 05 - 1999

Date of mailing (day/month/year) 25 March 1999 (25.03.99)		IMPORTANT NOTICE	
Applicant's or agent's file reference 2971070PC/TA			
International application No. PCT/FI98/00705	International filing date (day/month/year) 09 September 1998 (09.09.98)	Priority date (day/month/year) 12 September 1997 (12.09.97)	
Applicant VTT et al			

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
- AU, BR, CN, EP, IL, JP, KP, KR, US

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:

AL, AM, AP, AT, AZ, BA, BB, BG, BY, CA, CH, CU, CZ, DE, DK, EA, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IS, KE, KG, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, OA, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW

The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on 25 March 1999 (25.03.99) under No. WO 99/14736

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a demand for international preliminary examination must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the national phase, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer: J. Zahra
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

REC'D 09 NOV 1999

WIPO PCT

Applicant's or agent's file reference 2971070PC/TA	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/FI98/00705	International filing date (day/month/year) 09.09.1998	Priority date (day/month/year) 12.09.1997
International Patent Classification (IPC) or national classification and IPC ₆ G10K 11/178		
Applicant VTT et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand 12.04.1999	Date of completion of this report 14.10.1999
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88	Authorized officer Leif Vingård / MR Telephone No. 08-782 25 00

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI98/00705

I. Basis of the report

1. This report has been drawn on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

☒ the international application as originally filed.

☐ the description, pages _____, as originally filed,
pages _____, filed with the demand,
pages _____, filed with the letter of _____,
pages _____, filed with the letter of _____.

☐ the claims, Nos. _____, as originally filed,
Nos. _____, as amended under Article 19,
Nos. _____, filed with the demand,
Nos. _____, filed with the letter of _____,
Nos. _____, filed with the letter of _____.

☐ the drawings, sheets/fig _____, as originally filed,
sheets/fig _____, filed with the demand
sheets/fig _____, filed with the letter of _____,
sheets/fig _____, filed with the letter of _____.

2. The amendments have resulted in the cancellation of:

☐ the description, pages _____

☐ the claims, Nos. _____

☐ the drawings, sheets/fig _____

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI98/00705

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**1. Statement**

Novelty (N)	Claims	<u>1-7</u>	YES
	Claims		NO
Inventive step (IS)	Claims	<u>1-7</u>	YES
	Claims		NO
Industrial applicability (IA)	Claims	<u>1-7</u>	YES
	Claims		NO

2. Citations and explanations

Cited documents:

- 1) GB 2.160.742 A
- 2) FR 2.438.796 A1
- 3) US 4.177.874 A
- 4) US 4.473.906 A
- 5) US 5.060.271 A
- 6) US 5.319.165 A
- 7) US 5.548.653 A

The invention relates to a method for attenuating sound in a duct. In the method, sound is detected by means of a detector and the attenuation is performed by means of two successive actuator elements. The invention also relates to equipment for attenuating sound in a duct. The equipment comprises a detector for detecting the sound to be attenuated and the attenuation is performed by means of two successive actuator elements producing a sound attenuating counter-sound.

A method for attenuating sound in ducts which involves two successive elements is previously known from ref. 1. The two elements are driven with delay to produce sounds which are in phase downstream of the second element but in anti-phase to the sound to be attenuated, thereby producing an attenuating counter-sound.

To digitally implement inter-channel delay in different elements occupies, however, a great amount of signal processing resources. Thus, the result will be an inconveniently long processing time if the equipment used does not have extensive capacity.

.../...

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI98/00705

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: V.

According to the gist of the invention, two successive monopole elements are arranged in such a way that both elements function as a dipole approximation and produce a needed monopole radiation. Further, a dipole control signal is fed to both elements at opposite phase and a monopole control signal is fed to the elements cophasally. This arrangement provides a method and equipment that allows the advantages of the above-mentioned method to be obtained without the mentioned disadvantages.

According to the performed search, the claimed invention is new and involves an inventive step. The industrial applicability of the claimed invention is obvious.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 2971070PC/TA	FOR FURTHER ACTION - See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
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<input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).
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I <input checked="" type="checkbox"/> Basis of the report
II <input type="checkbox"/> Priority
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IV <input type="checkbox"/> Lack of unity of invention
V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI <input type="checkbox"/> Certain documents cited
VII <input type="checkbox"/> Certain defects in the international application
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Date of submission of the demand 12.04.1999	Date of completion of this report 14.10.1999
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 8056 S-102 42 STOCKHOLM Facsimile No. 08-667 72 83	Authorized officer Leif Vingård / MR Telephone No. 08-782 25 00

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI98/00705

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 Nos. _____, filed with the letter of _____,
 Nos. _____, filed with the letter of _____.

☐ the drawings, sheets/fig _____, as originally filed,
 sheets/fig _____, filed with the demand
 sheets/fig _____, filed with the letter of _____,
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☐ the drawings, sheets/fig _____

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI98/00705

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**1. Statement**

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A method for attenuating sound in ducts which involves two successive elements is previously known from ref. 1. The two elements are driven with delay to produce sounds which are in phase downstream of the second element but in anti-phase to the sound to be attenuated, thereby producing an attenuating counter-sound.

To digitally implement inter-channel delay in different elements occupies, however, a great amount of signal processing resources. Thus, the result will be an inconveniently long processing time if the equipment used does not have extensive capacity.

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI98/00705

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: V.

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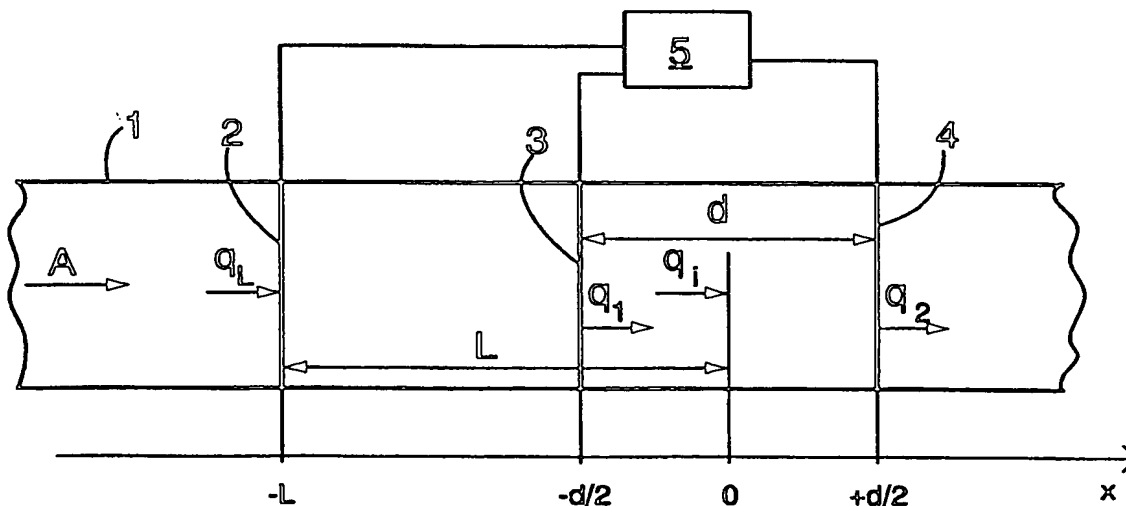
According to the performed search, the claimed invention is new and involves an inventive step. The industrial applicability of the claimed invention is obvious.



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : G10K 11/178	A1	(11) International Publication Number: WO 99/14736 (43) International Publication Date: 25 March 1999 (25.03.99)
<p>(21) International Application Number: PCT/FI98/00705</p> <p>(22) International Filing Date: 9 September 1998 (09.09.98)</p> <p>(30) Priority Data: 973677 12 September 1997 (12.09.97) FI</p> <p>(71) Applicant (for all designated States except US): VTT [FI/FI]; Vuorimiehentie 5, FIN-02150 Espoo (FI).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): UOSUKAINEN, Seppo [FI/FI]; Lehmustie 1 B, FIN-00780 Helsinki (FI). VALIMÄKI, Vesa [FI/FI]; Mäenrinne 7 as. 3, FIN-02160 Espoo (FI). KIRJAVAINEN, Kari [FI/FI]; Kivenlahdenkatu 11 A 4, FIN-02320 Espoo (FI). LEKKALA, Jukka [FI/FI]; Liinaharjankatu 10, FIN-33730 Tampere (FI). NYKÄNEN, Hannu [FI/FI]; Timpurinkatu 3, FIN-33720 Tampere (FI).</p> <p>(74) Agent: KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).</p>		<p>(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report.</p>

(54) Title: METHOD AND EQUIPMENT FOR ATTENUATING SOUND IN A DUCT



(57) Abstract

The invention relates to a method and an equipment for attenuating sound in a duct. Sound propagating in a duct is detected by means of a detector (2) and attenuated by using two successive monopole elements (3, 4) in such a way that both elements function as a dipole approximation and the elements are also used to approximatively produce the monopole radiation needed. A dipole control signal is fed to both elements (3, 4) at a phase shift which is 180° between the two elements. In addition, a monopole control signal is fed to the same elements (3, 4), only this time cophasally. Total volume velocities produced by the two elements (3, 4) are combinations of the portions obtained from the monopole and dipole sources.

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METHOD AND EQUIPMENT FOR ATTENUATING SOUND IN A DUCT

The invention relates to a method for attenuating sound in a duct, the sound to be attenuated being detected in the method by means of a
5 detector and the attenuation being performed by means of two successive actuator elements.

The invention also relates to an equipment for attenuating sound in a duct, the equipment comprising a detector for detecting the sound to be attenuated and two successive actuator elements for producing a sound
10 attenuating counter-sound.

One of the methods presented for attenuating sound in ducts is a method known as the Swinbanks method, in which an attenuation sound is produced by means of two successive elements. Both elements produce a volume velocity of an equal amplitude, the volume velocities being, however,
15 of opposite phases. In addition, to the element that is first in the direction of propagation of the sound to be attenuated is caused a delay proportional to the distance between the elements. A unidirectional, radiating element is thereby obtained, i.e. no acoustic feedback is caused to the detector measuring the sound to be attenuated. Instead, a signal is generated that only
20 attenuates forward the sound of the sound source to be attenuated. To digitally implement inter-channel delay in different elements occupies, however, a great amount of signal processing resources, which means that the equipment to be used must have an extensive capacity and/or the processing time becomes inconveniently long.

25 An object of the present invention is to provide a method and an equipment that will allow the advantages of the above mentioned method to be obtained, avoiding, however, the above disadvantages.

A method of the invention is characterized in that sound is attenuated by means of two successive monopole elements in such a way that
30 both elements function as a dipole approximation and also produce a monopole radiation needed, a dipole control signal being fed to both elements at a phase shift which is 180° between the two elements and a monopole control signal being fed to the elements cophasally.

Further, an equipment of the invention is characterized in that the
35 actuator elements are monopole elements which are arranged to function as a dipole approximation and to also produce the monopole radiation needed and

that the equipment comprises means for feeding the dipole control signal to both elements at a phase shift which is 180° between the two elements and for feeding a monopole control signal to the elements cophasally.

5 An essential idea of the invention is that sound is attenuated by means of two successive monopole elements in such a way that both elements function as a dipole approximation and that, in an equal manner, they are also used for approximating the monopole radiation needed. The dipole control signal is fed to both elements at a phase shift which is 180° between the two elements. The monopole control signal is also
10 fed to the same elements, only this time cophasally. Total volume velocities produced by both elements are combinations of the portions obtained from the monopole and dipole sources. An idea of a preferred embodiment is that control signals are specified by means of suitable control functions.

15 An advantage of the invention is that the equipment does not produce acoustic feedback between an actuator and the detector, because the equipment provides a unidirectional signal. In addition, the equipment is simple and in the control system of the equipment there is no inter-channel delay in the different elements, so when the equipment is used it is possible to apply simple algorithms and short processing times, while maintaining at the
20 same time a good performance level. The use of control functions for specifying and correcting control signals allows an almost ideal system functionality to be obtained also at higher frequencies.

25 The term 'duct' is used in the present application to refer to a duct or a conduit, or the like, in which sound propagates substantially in only two directions at frequencies low enough.

The invention will be described in greater detail in the attached drawings, in which

Figure 1 is a schematic side view, in section, of an equipment of the invention;

30 Figure 2 is a diagram illustrating a control system of the invention;

Figure 3 illustrates a control function of a dipole part; and

Figure 4 illustrates a control function of a monopole part.

Figure 1 shows a duct 1. Sound appearing in the duct 1, caused by a sound source, is depicted with an arrow A. At a point $x = -L$ is arranged a
35 detector 2 which is used for detecting the sound caused by the sound source. In the direction of sound propagation, a first actuator element 3 is placed after

the detector 2 at a point $x = -d/2$ and a second actuator element 4 is placed after the first one at a point $x = +d/2$, the actuator elements 3 and 4 being at a distance d from each other. The actuator elements 3 and 4 are monopole elements, therefore they do not impede the flow of a medium in the duct 1.

5 Figure 1 also schematically shows control means 5 for controlling actuator elements 3 and 4 on the basis of a signal received from the detector 2.

The first actuator element 3 produces a volume velocity q_1 and the second actuator element 4 produces a volume velocity q_2 . Both actuator elements 3 and 4 function as a dipole approximation in such a way that a

10 dipole control signal is fed to both elements 3 and 4 at a phase shift which is 180° between the two elements. In addition, a monopole control signal is fed to both elements 3 and 4, only this time cophasally. The total volume velocities q_1 and q_2 produced by the elements 3 and 4 are combinations of the portions obtained from monopole and dipole sources.

15 The volume velocity q_i describes the sound produced by the sound source at a point $x = 0$, the volume velocity q_i being proportional to the original sound pressure p_i such that

$$20 \quad q_1 = \frac{p_1 S}{\rho_0 c_0},$$

where S is the cross-sectional area of the duct, ρ_0 is the density of the medium in a static state and c_0 is the sound velocity in the medium.

25 The control signals of the actuator elements 3 and 4, i.e. the total volume velocities they produce, are

$$q_1 = \frac{1}{2}(1/jkd - \frac{1}{2})q_i, \quad x = -d/2$$

30 and

$$q_2 = -\frac{1}{2}(1/jkd + \frac{1}{2})q_i, \quad x = +d/2,$$

where

35 j is an imaginary unit;
 k is a wave number $= \omega/c_0$;

ω is an angular frequency;
 c_0 is sound velocity in a medium; and
 q_i is the original sound pressure to be attenuated,
 located at the point $x = 0$ and converted to a volume
 velocity quantity.

In the volume velocity expressions, the first parts relate to dipole radiation and the latter parts to monopole radiation.

The above described total volume velocities attenuate the sound produced by a sound source in the direction of propagation of the sound, and the actuator elements 3 and 4 do not radiate against the direction of sound of the sound source. At higher frequencies, however, the system does not function ideally, due to the approximative nature of the monopole and dipole radiation. Errors produced by the approximations can be compensated by means of suitable control functions. A dipole control function denoted by a quantity a and a monopole control function denoted by a quantity b allow the following total volume velocities to be obtained:

$$q_1 = \frac{1}{2}(a/jkd - b/2)q_i, x = -d/2,$$

and

$$q_2 = -\frac{1}{2}(a/jkd + b/2)q_i, x = +d/2.$$

The control system of the actuator elements 3 and 4 is shown as a diagram in Figure 2. In Figure 2 a quantity q_L denotes a signal measured by the detector 2, the signal being converted to a volume velocity quantity, and a delay τ_L denotes the time required for sound to propagate from the detector point $x = -L$ to the actuator system centre $x = 0$, i.e. $\tau_L = L/c_0$, where c_0 denotes sound velocity in the medium. The delay in question can be estimated and implemented by means of an adaptive filter. In the embodiment shown in Figure 2 the imaginary unit j is replaced with an integrator, which allows the previously needed 90° phase shift and also the singularity of the control function at the frequency 0 to be avoided.

Errors produced by the approximations can be corrected for instance by applying the following dipole part control function

$$a = \frac{kd/2}{\sin(kd/2)}$$

5

and the following monopole part control function

$$b = \frac{1}{\cos(kd/2)}.$$

10

A graph illustrating the dipole part control function a is shown in Figure 3 and a graph illustrating the monopole part control function b is shown in Figure 4. A quantity λ in Figures 3 and 4 denotes wave length. Monopole control is singular when $d = \lambda/2$. The continuous frequency area available is thus restricted to a frequency corresponding to the wave length in question.

The drawings and the related description are only meant to illustrate the inventive idea. The details of the invention may vary within the scope of the claims. An arrangement of the invention can thus also be used in a detector implementation. The most ideal function of an arrangement of the invention is obtained when the frequency is sufficiently low, ensuring that sound propagates only in a plane wave form only in the duct. The duct is most advantageously sufficiently long, so as to ensure that reflections from the duct ends do not affect the final result. In addition, the walls of the duct are most advantageously so hard that duct wall impedance need not to be taken into account. Further, the medium in the duct is most advantageously homogenous and motionless, sound velocity being equally high at every point of the duct and not dependent on the direction of sound propagation. Further, the medium is most advantageously so ideal that viscosity or thermal loss do not affect the final result.

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CLAIMS

1. A method for attenuating sound in a duct, the sound to be attenuated being detected in the method by means of a detector (2) and the attenuation being performed by means of two successive actuator elements (3, 4), **characterized** in that sound is attenuated by means of two successive monopole elements (3, 4) in such a way that both elements (3, 4) function as a dipole approximation and also produce a monopole radiation needed, a dipole control signal being fed to both elements (3, 4) at a phase shift which is 180° between the two elements and a monopole control signal being fed to the elements (3, 4) cophasally.

2. A method according to claim 1, **characterized** in that the control signal of the first actuator element (3) is

$$q_1 = \frac{1}{2}(a/jkd - b/2)q_i,$$

and the control signal of the second actuator element (4) is

$$q_2 = -\frac{1}{2}(a/jkd + b/2)q_i,$$

where

j is an imaginary unit;

k is a wave number = ω/c_0 ;

ω is an angular frequency;

c_0 is sound velocity in a medium;

d is a distance between the actuator elements (3, 4);

q_i is the sound pressure to be attenuated, located at the centre of the actuator elements (3, 4), and converted to a volume velocity quantity;

a is a constant or a dipole part control function; and

b is a constant or a monopole part control function.

3. A method according to claim 2, **characterized** in that a is a dipole part control function and b is a monopole part function such that

$$a = \frac{kd/2}{\sin(kd/2)}$$

and

$$b = \frac{1}{\cos(kd/2)}.$$

4. A method according to claim 2 or 3, **characterized** in that in the control signals (q_1 , q_2) of the elements the impact of the imaginary unit is determined by using an integrator.

5. An equipment for attenuating sound in a duct, the equipment comprising a detector (2) for detecting the sound to be attenuated and two successive actuator elements (3, 4) for producing a sound attenuating counter-sound, **characterized** in that the actuator elements (3, 4) are monopole elements which are arranged to function as a dipole approximation and to also produce a necessary monopole radiation and that the equipment comprises means for feeding a dipole control signal to both elements (3, 4) at a phase shift which is 180° between the two elements and for feeding a monopole control signal to the elements (3, 4) cophasally.

6. An equipment according to claim 5, **characterized** in that the control signal of the first actuator element (3) is

$$q_1 = \frac{1}{2}(a/jkd - b/2)q_i,$$

and the control signal of the second actuator element (4) is

$$q_2 = -\frac{1}{2}(a/jkd + b/2)q_i,$$

where

j is an imaginary unit;
 k is a wave number $= \omega/c_0$;
 ω is an angular frequency;
 c_0 is sound velocity in a medium;
 d is a distance between the actuator elements (3, 4);
 q_i is the sound pressure to be attenuated, located at the centre of the actuator elements (3, 4), and converted to a volume velocity quantity;
 a is a constant or a dipole part control function; and
 b is a constant or a monopole part control function.

7. An equipment according to claim 6, **characterized** in that a is a dipole part control function and b is a monopole part function such that

$$a = \frac{kd/2}{\sin(kd/2)}$$

and

$$b = \frac{1}{\cos(kd/2)}.$$

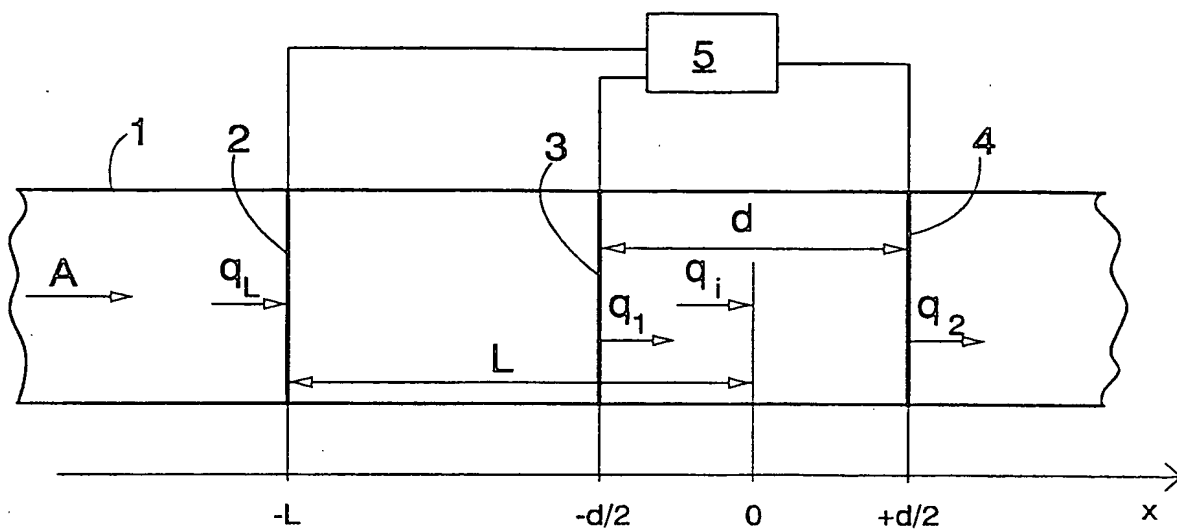


FIG. 1

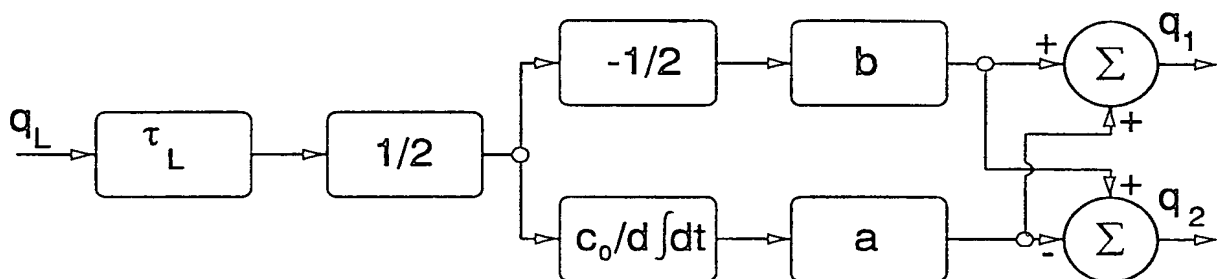


FIG. 2

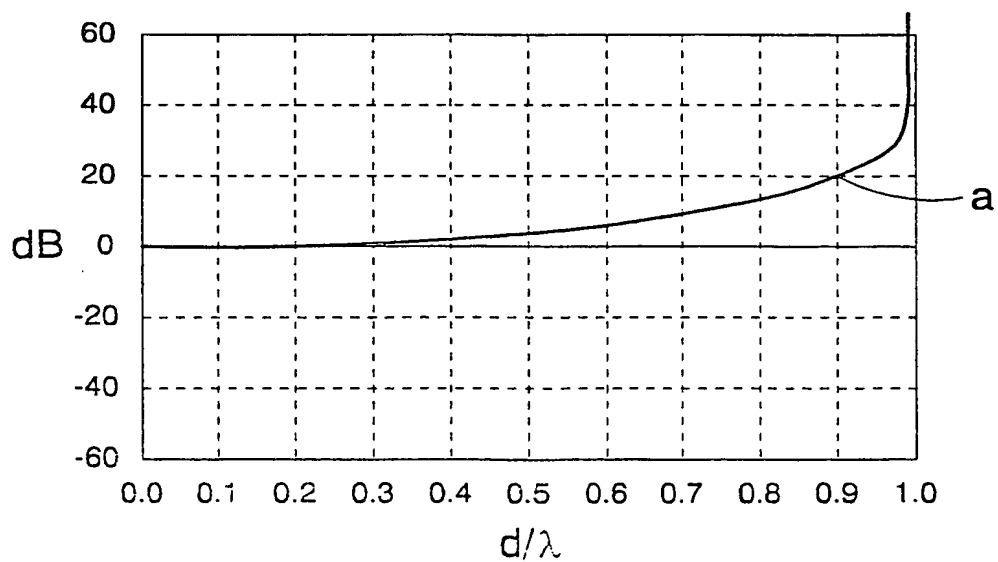


FIG. 3

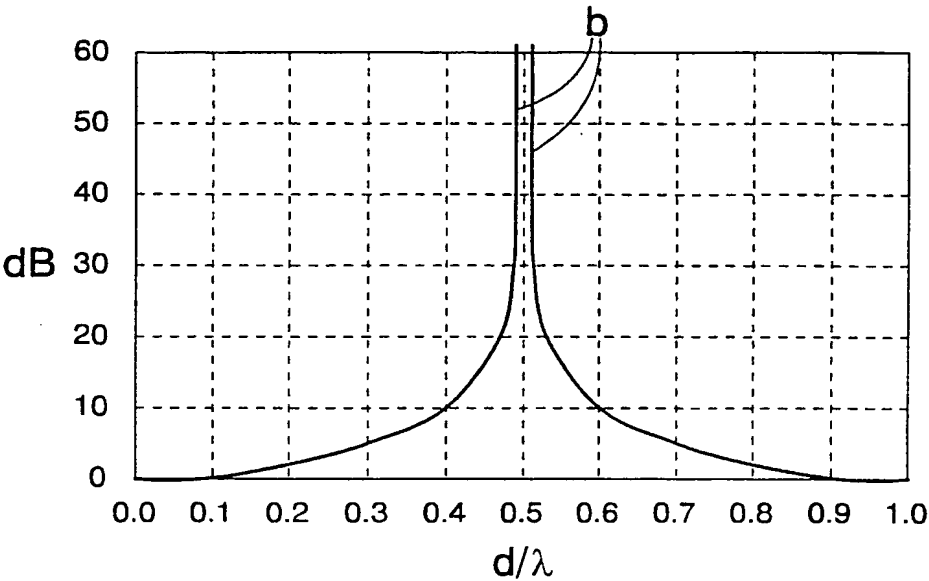


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 98/00705

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G10K 11/178

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F01N, F16L, F24F, G10K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPOQUE, EPODOC, PAJ, WPI, TXTE, TXTG, TXTF, COMBI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	FR 2438796 A1 (AGENCE NATIONALE DE VALORISATION DE LA RECHERCHE - A.N.V.A.R.), 9 May 1980 (09.05.80) --	1,5
A	US 4177874 A (ANGELINI ET AL), 11 December 1979 (11.12.79) --	1,5
A	US 4473906 A (WARNAKA ET AL), 25 Sept 1984 (25.09.84) --	1,5

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5319165 A (GEDDES), 7 June 1994 (07.06.94) --	1,5
A	US 5548653 A (PLA ET AL), 20 August 1996 (20.08.96) -- -----	1,5

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/12/98

International application No.

PCT/FI 98/00705

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US	5548653	A	20/08/96	NONE	

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